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EXPERIMENTAL ECONOMICS: THEORY AND RESULTS

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EXPERIMENTAL ECONOMICS:
SOME THEORY AND RESULTS

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I. INTRODUCTION

Microeconomics, including the study of individual choice and the theory of markets has generally been considered a field science not an experimental laboratory science. In econometric theory and estimation the concept of a controlled experiment generating economic data is sometimes used to explicate ideal techniques of hypothesis testing. But the experimental laboratory is considerably more important to economic science than to serve as an imaginary construct employed to clarify and to qualify the interpretation of our regression results from aggregate time series and from nonscientific observations on firms and households. There are two distinct reasons for this:

1. The results of laboratory studies can serve as a rigorous empirical pre-test of economic theory prior to the use of field data tests. The state of economic hypothesis testing, as it is sometimes done, can be described roughly as follows. Based on casual observation of the characteristics of a particular market or industry and the self-interest postulate, one writes down a model satisfying all the requirements of internal logical consistency. The model is then tested with the only body of field data that exists.

The results of the test turn out to be ambiguous, or in any case to call for improvements, and one is tempted to now modify the model in ways suggested by the data "to improve the fit." This is of course quite unsatisfactory since any test of significance becomes hopelessly confused if one now attempts to apply it to the same data. Where it is possible and feasible, as in the study of price formation, the data from controlled experiments can be used to test hypotheses stemming from prescientific casual observations of a particular phenomenon. The fact that one can always run a new experiment means that it is never tautological to modify the model in ways suggested by the results of the last experiment. Since economic theories always deal with certain alleged behavioral tendencies in isolation, the experimental laboratory is uniquely well suited for testing the validity of such theories. It provides an exceptionally rigorous discipline of our ability to model elementary situations whether or not field data can be regarded ultimately as having been generated by such elementary models.

2. The results of experiments can be directly relevant to the study and interpretation of field data. Other so-called nonexperimental sciences such as meteorology and astronomy have depended crucially for their development on (1) small-scale laboratory experiments in the physics of mass motion, thermodynamics, and nuclear reactions; and (2) the postulate that such microphysical experimental results apply, with suitable modifications, to the study of the weather, the planets and the stars. This parallelism, "As far as we can tell, the same physical laws prevail everywhere" (Shapley, 1964, p. 43), also has application to the study of social economy. Laboratory experience suggests that all of the characteristics of "real world" behavior that we consider to be of primitive importance -- such as self-interest motivation, interdependent tastes, risk aversion,

subjective transactions cost (time is consumed), costly information (it takes time to acquire and process information), and so on -- all arise naturally, indeed inevitably, in experimental settings. Anyone who had begun the study of economics in the laboratory without these concepts, would soon find himself inventing them. Furthermore the process of experimental design forces one to articulate rules and procedures, the collection of which, forms an institution, organization, or "body of law" with striking "real world" parallels. It is impossible to do market experiments without inventing fiat money, contracts, credit rules, and whole exchange institutions (cf. Shubik, 1974). The laboratory becomes a place where real people earn real money for making real decisions about abstract claims that are just as "real" as commercial paper, a share of General Motors, or a contract to deliver wheat on May 10.

It is the premise of this paper that the study of the decision behavior of suitably motivated individuals and groups in laboratory or other socially isolated settings such as hospitals (Battalio, Kagel, et al., 1973) has important and significant application to the development and verification of theories of the economic system at large.

II. THE THEORY OF INDUCED VALUATION

Control is the essence of experimental methodology, and in experimental exchange studies it is necessary that one be able to state that as between two experiments individual values (e.g. demand or supply) either do or do not differ in a specified way. Such control can be achieved by using a reward structure to induce prescribed monetary value on abstract experimental objects or actions. The concept of induced valuation depends upon the following postulate:

> Nonsatiation: Given a costless choice between two alternatives, identical except that the first yields more of the reward medium (usually currency) than the second, the first will always be chosen (preferred) over the second, by an autonomous individual, i.e. utility is a monotone increasing function of the monetary reward, $U(M)$, $U' > 0$.

Example 1: In the experimental study of competitive equilibria in isolated markets it is necessary to induce known (to the experimenter) supply or demand on individual subjects. Let subject buyers $i = 1, 2, \ldots, n$ each be given a table listing increasing concave total receipts $R_i(q_i)$ representing the currency redemption or "resale" value of q_i units acquired by subject i in an experimental market. The instructions state that if subject i acquires q_i units at prices $p_1^i, p_2^i, \ldots, p_{q_i}^i$, he will receive cash earnings of $R_i(q_i) - \sum_{k=1}^{q_i} p_k^i$.

Neoclassical demand is defined as the quantity that would be purchased as a function of a given hypothetical price p. By this definition if for a fixed p a subject purchases q_i units, he earns $R_i(q_i) - pq_i$. If his utility for money is $U_i(M_i)$ he will wish to $\max_{q_i} U_i[R_i(q_i) - pq_i]$.

We have an interior maximum if and only if

$$\frac{dU_i}{dq_i} = (R_i' - p)U_i' = 0,\ U_i' > 0,\ \text{or } q_i = R'^{(-1)}(p),$$

for the class of functions U_i, R_i such that

$$\frac{d^2U_i}{dq_i^2} = (R_i' - p)^2 U_i'' + U_i' R_i'' < 0$$

Given any set of n increasing concave functions, $R_i(q_i)$, such that $\frac{d^2U_i}{dq_i^2} < 0$, this reward scheme induces arbitrary demand $R_i'^{(-1)}(p)$ on subject i, and the experimentally controlled market demand becomes

$Q = \sum_{i=1}^{n} R_i'^{(-1)}(p)$ independent of the U_i.

Similarly, let $j = 1, 2, \ldots, m$ subject sellers be given cost functions $C_j(q_j)$, and receive cash earnings $\sum_{k=1}^{q_j} p_k^j - C_j(q_j)$ from selling q_j units at prices $p_1^j, p_2^j, \ldots, p_{q_j}^j$. If utility is $V_j(M_j)$, $V_j' > 0$, then $\max_{q_j} V_j[pq_j - C_j(q_j)]$ implies a supply function $q_j = C_j'^{(-1)}(p)$. The experimentally controlled market supply is $Q = \sum_{j=1}^{m} C_j'^{(-1)}(p)$ independent of the V_j.

The above induced supply and demand become flows per period in experiments in which trading is conducted in a sequence of trading periods (Smith, 1962, 1964).

Example 2: Let subject traders be given a table listing increasing concave currency receipts $M(x_1, x_2)$ to be paid by the experimenter for terminal stocks (x_1, x_2) of each of two abstract experimental commodities exchanged in an experimental general equilibrium market. Then subject i's unknown utility for currency $U_i(M)$ induces the value $U_i[M(x_1, x_2)]$ on terminal stocks (x_1, x_2). Consequently, the known, experimentally controlled indifference map given by the level contours of $M(x_1, x_2)$ are induced upon subject i independent of his particular U_i. That is, each subject's marginal rate of substitution of x_2 for x_1 is given by $U_i' M_1 / U_i' M_2 = M_1 / M_2$, $U_i' > 0$. This allows the "Edgeworth Box" representation of general exchange equilibrium to be reproduced experimentally by inducing a given indifference map on each member of one group of subjects, and another indifference map on each of a second group of subjects. With given endowments of the abstract commodities for members of each of the two trading groups, the experimental stage is set for exchange. A subject with initial endowment $(\bar{x}_1, 0)$ will have an induced demand for x_2 defined by $M_2(x_1, x_2)/M_1(x_1, x_2) = p$, $\bar{x}_1 = x_1 + px_2$.

III. SOME QUALIFICATIONS

There are three important qualifications to the above theory which stem in part from the adjectives "costless" and "autonomous" in the nonsatiation postulate.

1. There may be subjective costs (or values) associated with the making or execution of market decisions.

In a competitive market experiment a subject may find it arduous to monitor quotations, make his own quotations, and execute transactions. If such considerations are not negligible, then we lose some control over the process of induced valuation. The effect of boredom and the subjective costs of decision making has been emphasized in the important study by Siegel (1961). Sherman (1974) has interpreted alleged violations of the Savage axioms in terms of the subjective cost of making the appropriate computations. In terms of the utility interpretation of the previous section, the utility function can now be written $U^i(M_i, E_i)$ where E_i is the "transactional effort" required to obtain reward M_i (cf. Liebenstein, 1969; and implicitly, Coase, 1960). To see the potential implications of costly choice, consider example 1 of the previous section in which demand $R_i'^{(-1)}(p)$ is induced upon i. Suppose i's utility is now $U^i\{R_i[q_i(E_i)] - pq_i(E_i), E_i\}$ where it is assumed crudely that "bargaining effort," E_i, results in the purchase quantity $q_i(E_i)$. Then $\max_{E_i} U^i$ implies $(R_i' - p)q_i'U_1^i + U_2^i = 0$, and now the induced demand is $q_i = R_i'^{(-1)}(p - U_2^i/U_1^i q_i') < R_i'^{(-1)}(p)$, if $U_2^i < 0$, $q_i' > 0$. Hence, if there is a cost (value) to transacting in the experimental task, the induced demand will be smaller (larger).

There are several ways of dealing with this problem:

(a) One is to examine the experimental results to see if the quantity exchanged is less than predicted. If it is, this is consistent with a

significant transactions cost. Awareness of such transactions cost effects provides a valuable clue to understanding why certain experiments may fail to produce predicted results. The process is not tautological as long as one can redesign the experiment and show that such conjectured transactional effects can be reduced.

(b) Another approach is to use a reward structure to compensate for, or offset, the subjective costs of transacting. There are two ways of doing this. (i) One way (Siegel, 1961) is to simply raise the reward level. This increases the subjective value relative to the subjective cost of acquiring units q_i. Let α be a scale parameter determining reward level. Then utility becomes $U^i\{\alpha(R_i[q_i(E_i)] - pq_i(E_i)), E_i\}$.

Induced demand is now $q_i = R_i'^{(-1)}(p - U_2^i/U_1^i q_i'\alpha) \longrightarrow R_i'^{(-1)}(p)$ in the limit as α increases provided that the marginal rate of substitution $-U_2^i/U_1^i q_i'$ decreases, or increases less than proportionally, with the reward level. If, for example, $U^i(M_i, E_i)$ is additive, then $\frac{d}{d\alpha}[-U_2^i/U_1^i q_i'] < 0$ and $\lim_{\alpha\to\infty} [-U_2^i/U_1^i q_i'\alpha] \longrightarrow 0$. (ii) Alternatively, and this is the device used most extensively, subjects are promised a slight commission, β (I use 5 cents), for <u>each</u> transaction in addition to their cash trading profits. Now utility is $U^i\{R_i[q_i(E_i)] - (p - \beta)q_i(E_i), E_i\}$, and induced demand is

$$q_i = R_i'^{(-1)}(p - \beta - U_2^i/U_1^i q_i') \cong R_i'^{(-1)}(p) \text{ if } \beta \cong -U_2^i/U_1^i q_i' > 0.$$

Empirically, a 5 cent commission appears sufficient to induce subjects to trade their marginal units in most instances.

Compare two experiments (Plott and Smith, 1975, pp.) in which the induced supply and demand condition were identical but the first paid no cash trading commission, only trading profit, while the second paid both: In the first experiment volume was below (17-18 units) the "theoretical" equilibrium quantity (20 units) in all seven trading periods; in the second experiment volume was below (19 units) equilibrium in only two of eight trading periods.

2. Individuals may attach game value to experimental outcomes.

A profit in "points," $R_i(q_i) - pq_i$, may have subjective value $V_i[R_i(q_i) - pq_i]$. If V_i is monotone increasing then such game utilities create no methodological problems since they reinforce rather than distort the effect of an explicit monetary reward structure. Because of such game utilities it is often possible in simple-task experiments to get satisfactory results without monetary rewards by using instructions to induce value by role-playing behavior (i.e. "think of yourself as making a profit of such and such when . . . "). But such game values are likely to be weak, erratic, and easily dominated by transactions costs, and subjects may be readily satiated with "point" profits.

Qualifications 1 and 2 are illustrated in the convergence behavior of some experimental markets with no cash rewards (Charts 1, 2, and 3)[1] and some markets with complete and with random cash rewards (Chart 4).[2] In Charts 1-3 subjects were asked to imagine that trading profits and commissions were real. In each case (including 4) the market was organized as a continuous double auction. (Buyers could make oral bids and sellers oral offers for a single unit, and any seller could accept a bid, any buyer an offer. Each subject knew only his own demand or supply conditions.)(See Smith, 1964, pp. 199-201 for the instructions.) In Chart 1 each subject had a capacity to trade only one unit per trading period. The absence of cash rewards does not hinder convergence to prices near equilibrium by the third trading period. However, deviations increase in period 4. In the absence of cash rewards this is more likely to occur as gaming boredom follows an initial (pleasant) experience of learning.

Chart 2 is an experiment in which buyers received multiunit revenue (or resale value) schedules, and sellers multiunit total cost schedules. There were three buyers with one schedule, eight with

another; four sellers with one cost schedule, eight with another. The supply and demand graphs shown are the horizontal sums of the implied marginal revenue and cost schedules. Now the task of profit maximization is more difficult than in Chart 1, and incentives are weak. Price convergence is strong especially in the second period since the greater volume when traders are given multiple-unit capacities increases the learning experience within a trading period. But observe that volume is considerably below (24 and 26 units in the first and second periods) the competitive prediction (30 units). This is consistent with the above theory where the task is more difficult (higher transactions cost) and monetary rewards are absent.

Chart 3 illustrates an experiment which fails to reach either the competitive price or quantity although the market stabilizes nicely. In this case equilibrium requires contract prices to fall to the common limit price of all sellers. They are to "imagine" themselves as making a 5 cent commission on trades at these limit prices, but clearly this is not real enough to induce many contracts at \$3.10. Not even a decrease in demand succeeded in lowering contracts to \$3.10. This contrasts with Chart 4a and 4b consisting of two experiments with complete cash rewards in which the supply and demand are even more asymmetric than in Chart 3. Convergence to the competitive price and quantity is evident by trading period 4, although, at the equilibrium price, each buyer receives \$1.15 profit including commission per trade while each seller receives only the 5 cent commission. This design is a particularly rigorous test of the equilibrating power of the double auction (see Smith, 1965).

A controlled measurement of the effect of complete versus random monetary rewards is shown in Chart 4(a), (b) and (d). Three different subject groups participated in three double auction markets consisting of eleven buyers each with limit prices \$4.20 and sixteen

IV. TWO EXPERIMENTAL MARKETS WITH GROWING DEMAND

Hess (1972) has studied the effects of period-by-period changes in both supply and demand in an experimental double auction market. However, the subjects did not receive cash profit rewards and as we have seen above, this can effect outcomes in market experiments. The sequence of changed supply and demand was designed to create and reinforce the expectation that price rises a fixed amount (10 cents) each period. The effect of this expectation on the subsequent theoretical equilibria was determined in each of four different experimental sessions. This price expectation "treatment" was found to bias actual prices away from their theoretical values.

Arrow (1960) and Arrow and Capron (1959) have discussed price-quantity adjustments in competitive markets with rising demands. Assuming a linear rise in demand functions and a linear Walrasian adjustment process, Arrow proves several propositions briefly paraphrased as follows:

1. The shortage (defined as excess demand) increases from the initial value of 0 toward an asymptotic limit.

2. Prices rise, and the increase approaches a constant rate (usually positive) depending only on supply and demand conditions.

3. Actual price is always below the price that would clear the market.

These propositions also hold under the hypothesis of adaptive expectations, i.e. where the economic agent compares actual price with his previous expectation of it and then forms a new expectation by revising his previous expectation in the direction of the actual price (Arrow, 1960, pp. 11-13).

This section reports two experiments designed to approximate the conditions of the above propositions and to test their validity. In each experiment demand rises linearly over time, where

"time" is measured in terms of trading periods, and the experimental supply and demand conditions are approximately linear.

Subjects and Procedures

Twenty-seven subjects participated in the first experiment and forty-seven in the second. The instructions were those of the double auction (Smith, 1964, pp. 199-201) where both buyers and sellers are permitted to make oral quotations (bids or offers). Each buyer (seller) received a 5 cent commission in addition to the profit from exchange.

Experiment 1 consisted of six trading periods. At the end of each of the first four trading periods the buyers' cards were collected, and a new set of buyer limit prices, corresponding to an increase in demand, were distributed randomly among the buyers. Consequently, the highest limit buyer in period 1 would not be, except by accident, the highest limit buyer in period 2. The first five trading periods were characterized by the five demand arrays exhibited on the left of Chart 6. At the end of the fifth trading period the buyer limit cards were collected, just as in the previous periods, except that this time the new cards that were distributed corresponded to a repeat treatment of the period 5 demand condition. Hence, the subjects did not know at any time that the demand had increased in periods 2 through 5, nor that it had not increased in the case of period 6. They knew only what was obvious that buyers were receiving new limit price cards. Subject information consisted only of their private limit prices, and the sequence of verbal bids, offers, and contract prices that prevailed in each trading period.

Experiment 2 used approximately the same supply and demand conditions as in 1, except that seven trading periods were conducted with the six demand schedules shown on the left of Chart 7. In experiment 1 the subjects were Stanford University undergraduates; in experiment 2 the subjects were Purdue University undergraduates.

sellers each with limit prices $3.10. In 4(a) and 4(b) the subjects were all paid their trading profit plus commission in cash, while in 4(d) at the end of each trading period, four of the 27 subjects were chosen at random to receive cash profits. The chart demonstrates that the weaker random reward structure retards the market's equilibrium tendency. In period 4 of Chart 4(d) only one contract is at the equilibrium price, $3.10; this compares with five equilibrium contracts in 4(a) and eleven in 4(b).

Qualifications 1 and 2 lead to a precautionary corollary: With or without monetary rewards, the experimenter may be tempted to add "realism" by giving the abstract experimental commodity a name such as "wheat," or otherwise attempt to use instructions to simulate the alleged circumstances of a particular market. This runs the danger of so enriching induced values that control over valuation is lost. Suppose, as above, that a subject is paid $R_i(q_i) - pq_i$, but also perceives that he must attach instruction-induced value to q_i. Utility may now be $U^i[R_i(q_i) - pq_i, q_i]$, and demand becomes $q_i = R_i'^{(-1)}(p - U_2^i/U_1^i) > R_i'^{(-1)}(p)$. Consequently, it may be preferable <u>not</u> to embellish the instructions with well-intentioned attempts at realism. Let the explicit reward structure be the singular source of valuation, insofar as this is possible.

3. Individuals may not be autonomous own-reward maximizers.

Interpersonal utility criteria may qualify the theory of induced valuation. Thus subject i's utility may depend upon both i's and k's reward, $U^i[R_i(q_i) - pq_i, R_k(q_k) - pq_k]$. If this condition prevails, then the demand of i may depend upon that of k. However, this kind of interdependence is effectively controlled by the experimental condition of "incomplete" information, first defined and studied by Fouraker and Siegel (1960, 1963) in experimental studies of bilateral bargaining and oligopoly. Under incomplete information subjects only know their

own payoff contingencies. With $R_k(q_k) - pq_k$ unknown to i, it cannot appear as a subjective argument of U^i.

The effect when subjects have complete information (Fouraker and Siegel, 1963) on each other's payoff contingencies is seen in Charts 4 and 5 by comparing 4a (5a) and 4b(5b) with 4c(5c).[3] In 4a and 4b each subject knew only his own limit price. In 4c(5c) the only change in the instructions was to add the information that there were eleven buyers, each with a $4.20 resale value, and sixteen (nineteen in 5c) sellers, each with unit cost $3.10. From the transaction price series it is seen that "complete" information of this kind retards the equilibrium tendencies of the double auction. Contract prices in trading periods 2 through 4 tend to be higher under complete information than under incomplete information. The explanation is that with information on each other's payoffs, the way is open for "equity" considerations to modify self-interest choices. Sellers, believing that it is "fair" for trading profits to be shared between buyers and sellers, try to resist price decreases more vigorously than when they do not know what constitutes such a fair price. Buyers acquiesce in this sharing by accepting many contracts well above $3.10, but since there is an excess of sellers, those holding out for the higher prices are the sellers most likely to fail to make contracts. Consequently, contract prices tend to decline, if slowly, when excess supply is 5, but more rapidly when excess supply is 8. The tendency of prices to be higher under complete information is contrary to the view of Knight (1933, p. 197) and other economists who have argued that "perfect" information was essential for establishing competitive prices. The results are consistent with the game-theoretic proposition that more information increases the prospect of collusion (Shubik, 1959, p. 171), and with the results of Fouraker and Siegel (1963, p. 187) in which the tendency of the competitive equilibrium to prevail under duopoly bargaining is reduced under complete information.

Experimental Results and Discussion

The response of contract prices in experiments 1 and 2 is graphed on the right in Charts 6 and 7. Contract prices tend to be equal to or below the theoretical equilibrium in the first three periods of each experiment. In experiment 1 (2), only one (three) of the fifteen contracts in periods 1 to 3 were above equilibrium. But in period 5 of experiment 1 only one contract is below the theoretical equilibrium, and in experiment 2, period 6, only three of thirteen contracts are below equilibrium. Proposition 3 clearly fails in period 5 of experiment one and period 6 of experiment 2. Using a t test on the means of contract prices in these two periods, we are decidedly unable to reject the null hypothesis (proposition 3 is taken as the research hypothesis) that the data came from populations with means in excess of $3.00 in experiment 1 and $3.125 in experiment 2. In each experiment the experience of rising prices eventually produced expectations that caused sellers to raise their offers (and buyers to accept) above the theoretical equilibrium.

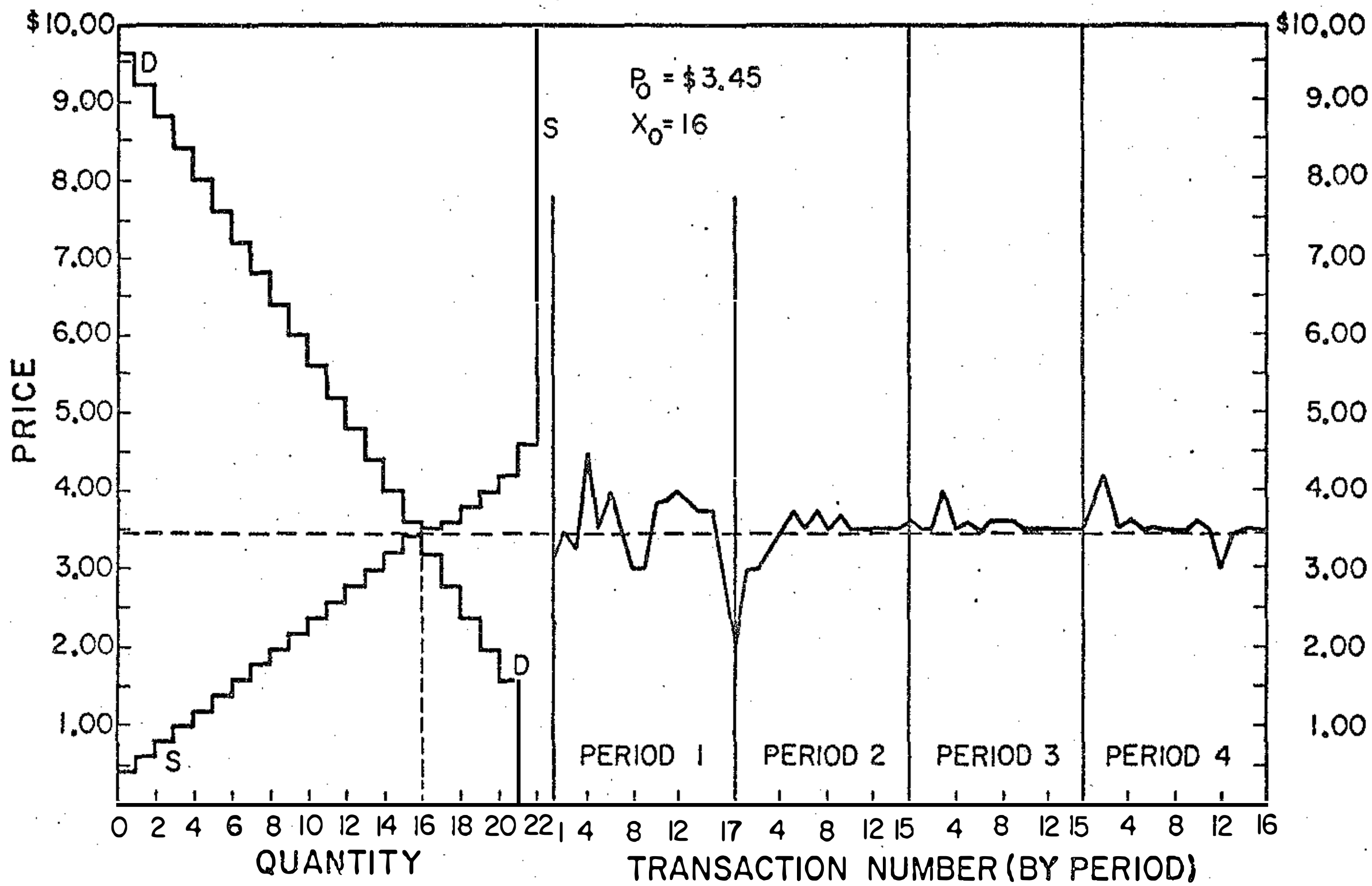
Evidence contrary to proposition 1 is shown in Table 1. The "shortage" is interpreted as excess demand prevailing at the mean contract price. The proposition is violated in period 5 of experiment 1 and periods 4, 5, and 6 of experiment 2.

These tests add further weight to the evidence that macromarket adjustment mechanisms such as the Walrasian (Smith, 1965) and the cobweb hypotheses (Carlson, 1967) are unsatisfactory.

TABLE 1

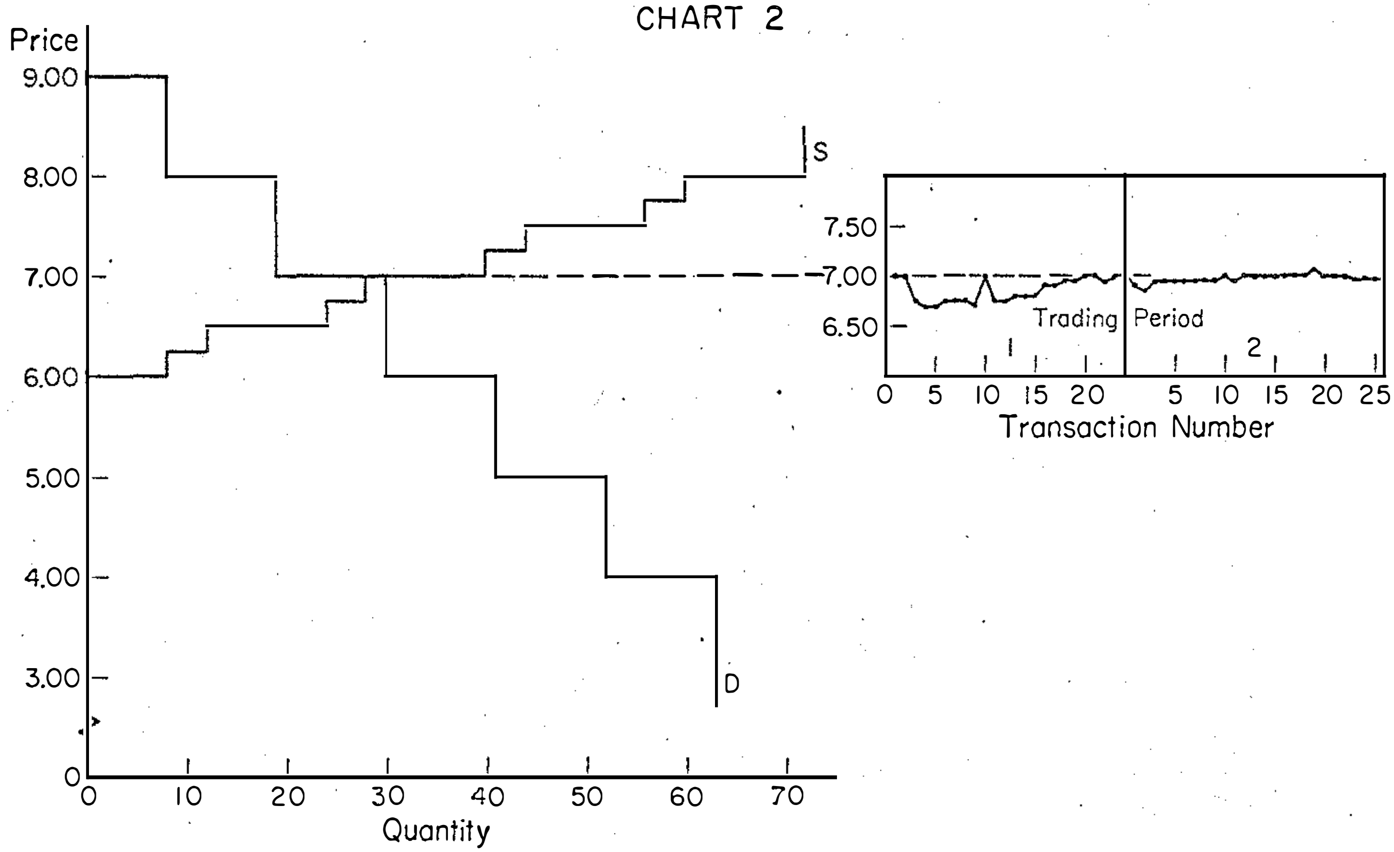
	Experiment 1		Experiment 2	
Period	Mean Price	Shortage	Mean Price	Shortage
1	2.20	0	2.10	2
2	2.36	1	2.34	2
3	2.53	2	2.40	4
4	2.73	2	2.725	0
5	3.05	-1	2.904	0
6			3.219	-3

CHART 1



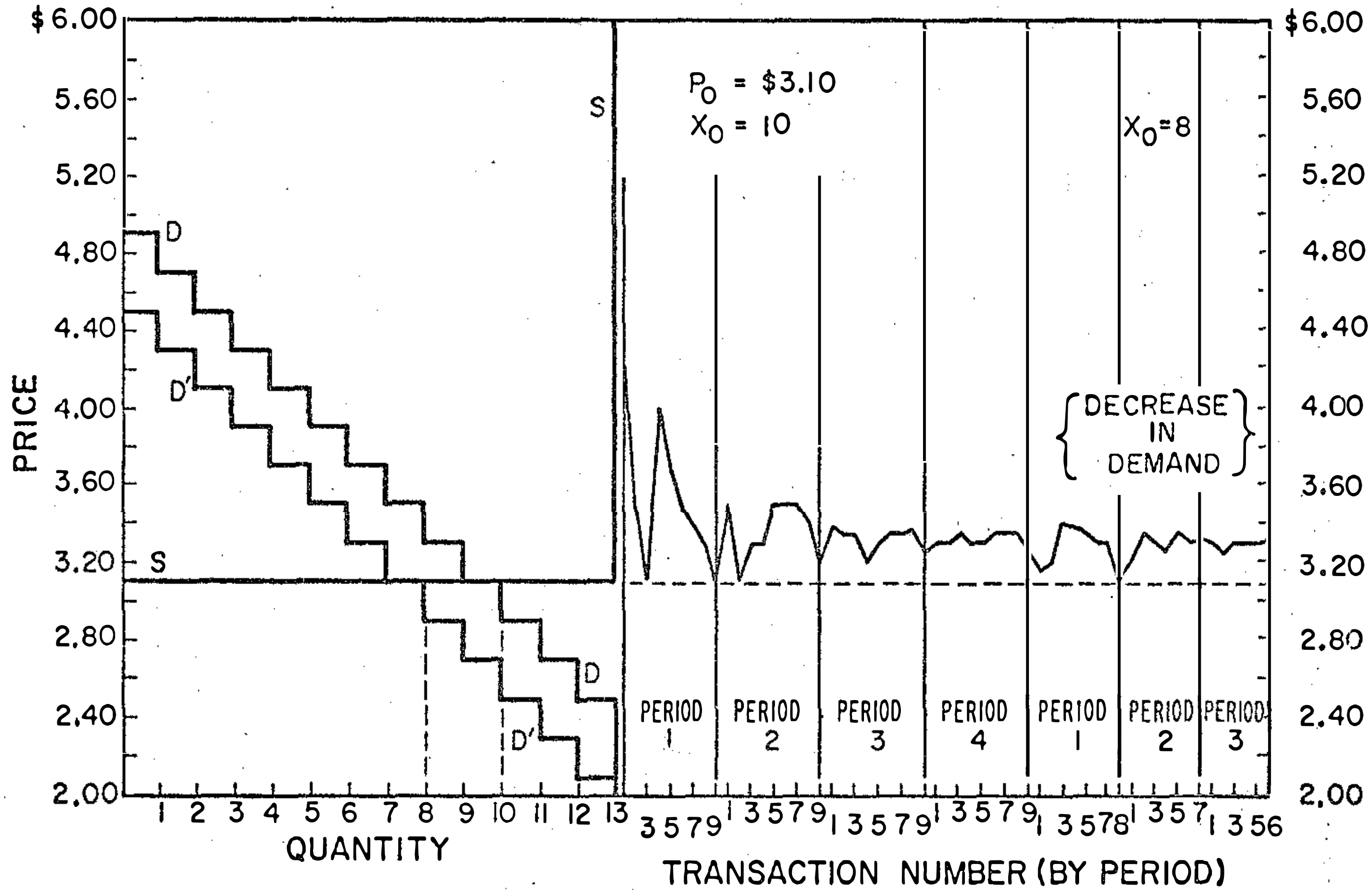
$10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
PRICE
D
S
S
D
P0 = $3.45
X0 = 16
PERIOD 1
PERIOD 2
PERIOD 3
PERIOD 4
0 2 4 6 8 10 12 14 16 18 20 22
QUANTITY
1 4 8 12 17 4 8 12 15 4 8 12 15 4 8 12 16
TRANSACTION NUMBER (BY PERIOD)

CHART 2



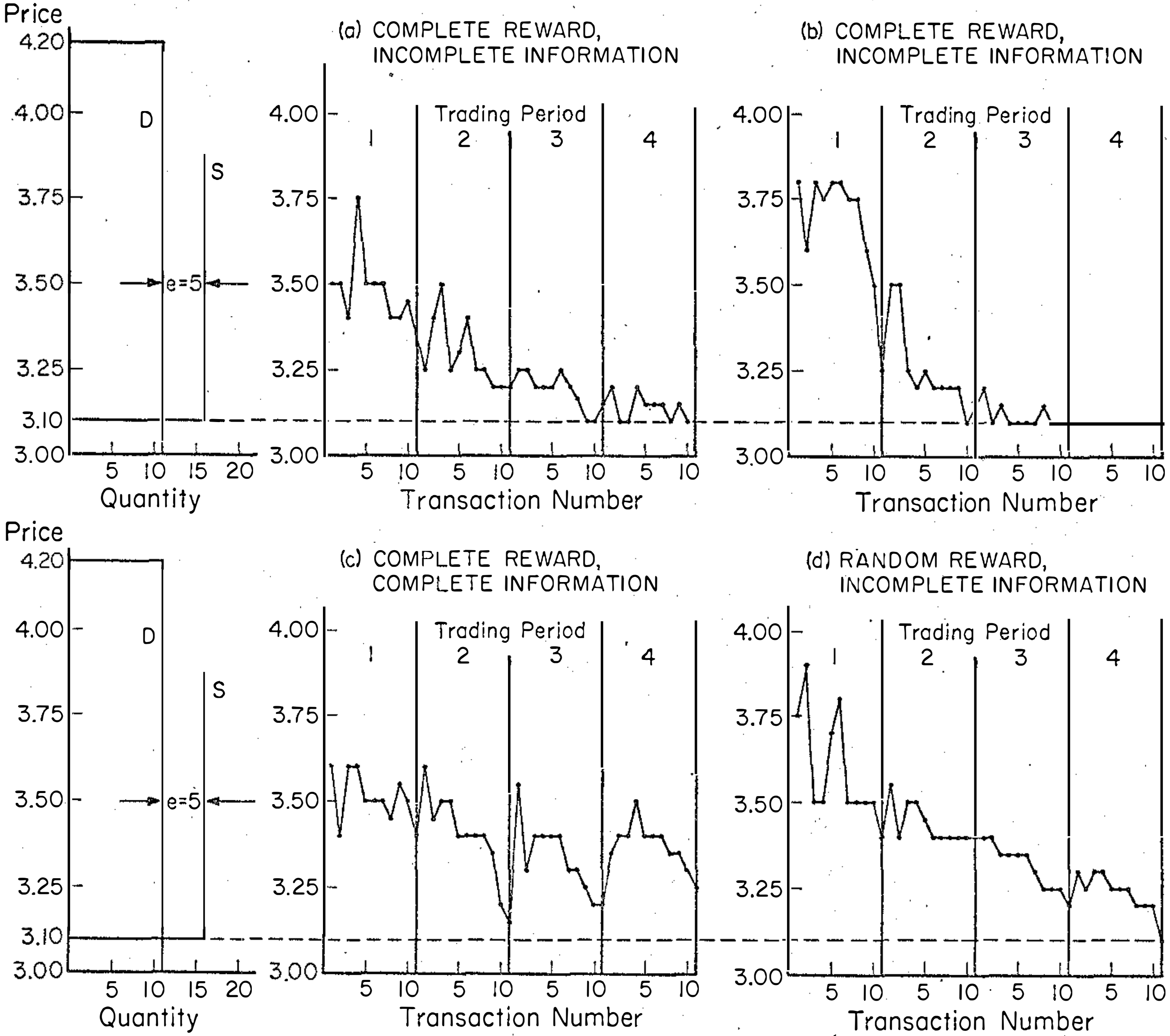
Price
9.00
8.00
7.00
6.00
5.00
4.00
3.00
0
0
10
20
30
40
50
60
70
Quantity
S
D
7.50
7.00
6.50
Trading Period
1
2
0 5 10 15 20
5 10 15 20 25
Transaction Number

CHART 3



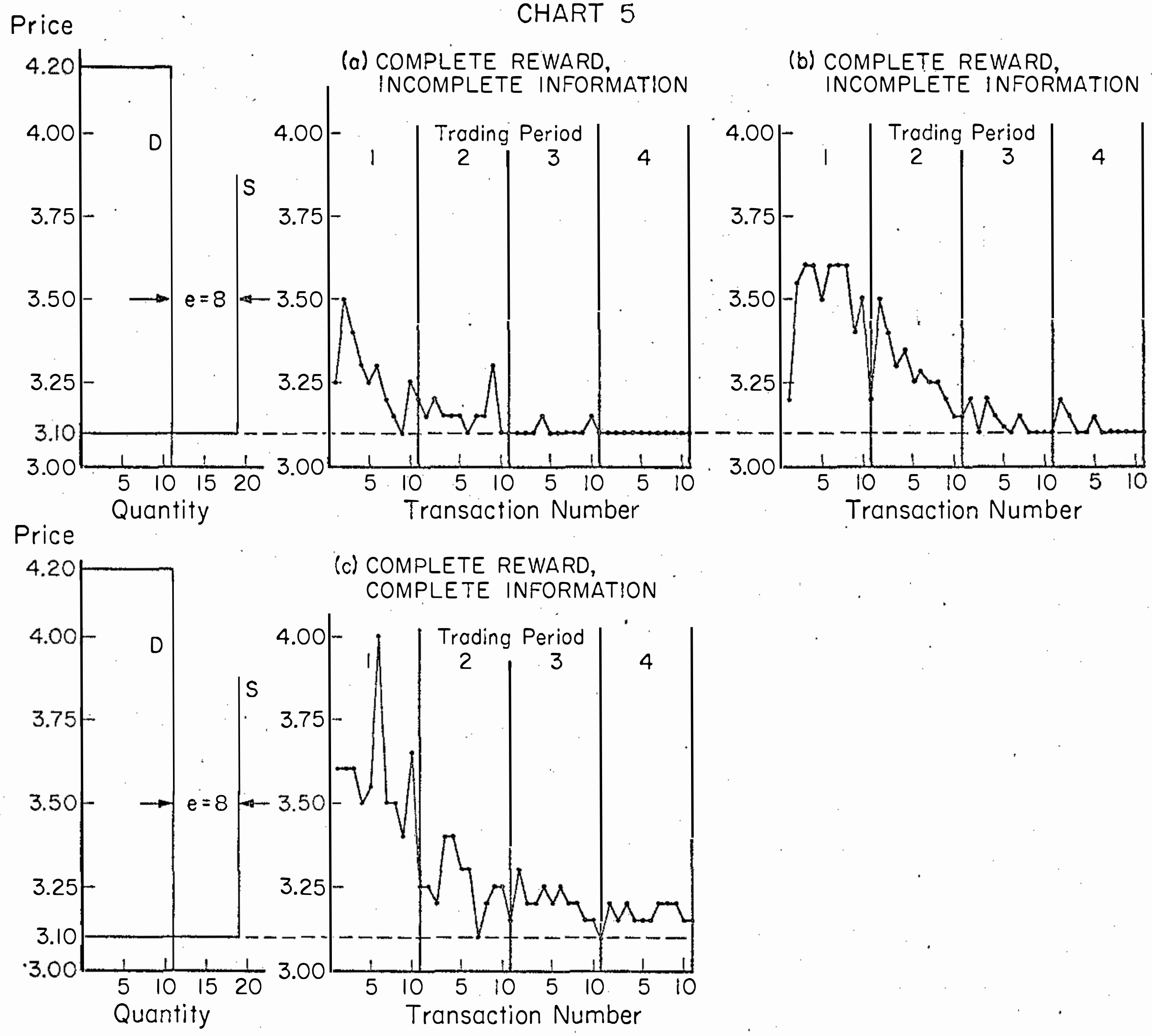
$6.00
5.60
5.20
4.80
4.40
4.00
3.60
3.20
2.80
2.40
2.00
PRICE
D
D'
S
QUANTITY
1 2 3 4 5 6 7 8 9 10 11 12 13
P_0 = $3.10
X_0 = 10
X_0=8
DECREASE IN DEMAND
PERIOD 1
PERIOD 2
PERIOD 3
PERIOD 4
PERIOD 1
PERIOD 2
PERIOD 3
TRANSACTION NUMBER (BY PERIOD)

CHART 4



Price
4.20
4.00
3.75
3.50
3.25
3.10
3.00
D
S
e=5
5 10 15 20
Quantity
(a) COMPLETE REWARD, INCOMPLETE INFORMATION
(b) COMPLETE REWARD, INCOMPLETE INFORMATION
(c) COMPLETE REWARD, COMPLETE INFORMATION
(d) RANDOM REWARD, INCOMPLETE INFORMATION
Trading Period
1
2
3
4
Transaction Number

CHART 5



Price
4.20
4.00
3.75
3.50
3.25
3.10
3.00
D
S
e=8
5 10 15 20
Quantity
(a) COMPLETE REWARD, INCOMPLETE INFORMATION
Trading Period
1 2 3 4
Transaction Number
(b) COMPLETE REWARD, INCOMPLETE INFORMATION
Trading Period
1 2 3 4
Transaction Number
(c) COMPLETE REWARD, COMPLETE INFORMATION
Trading Period
1 2 3 4
Transaction Number

CHART 6

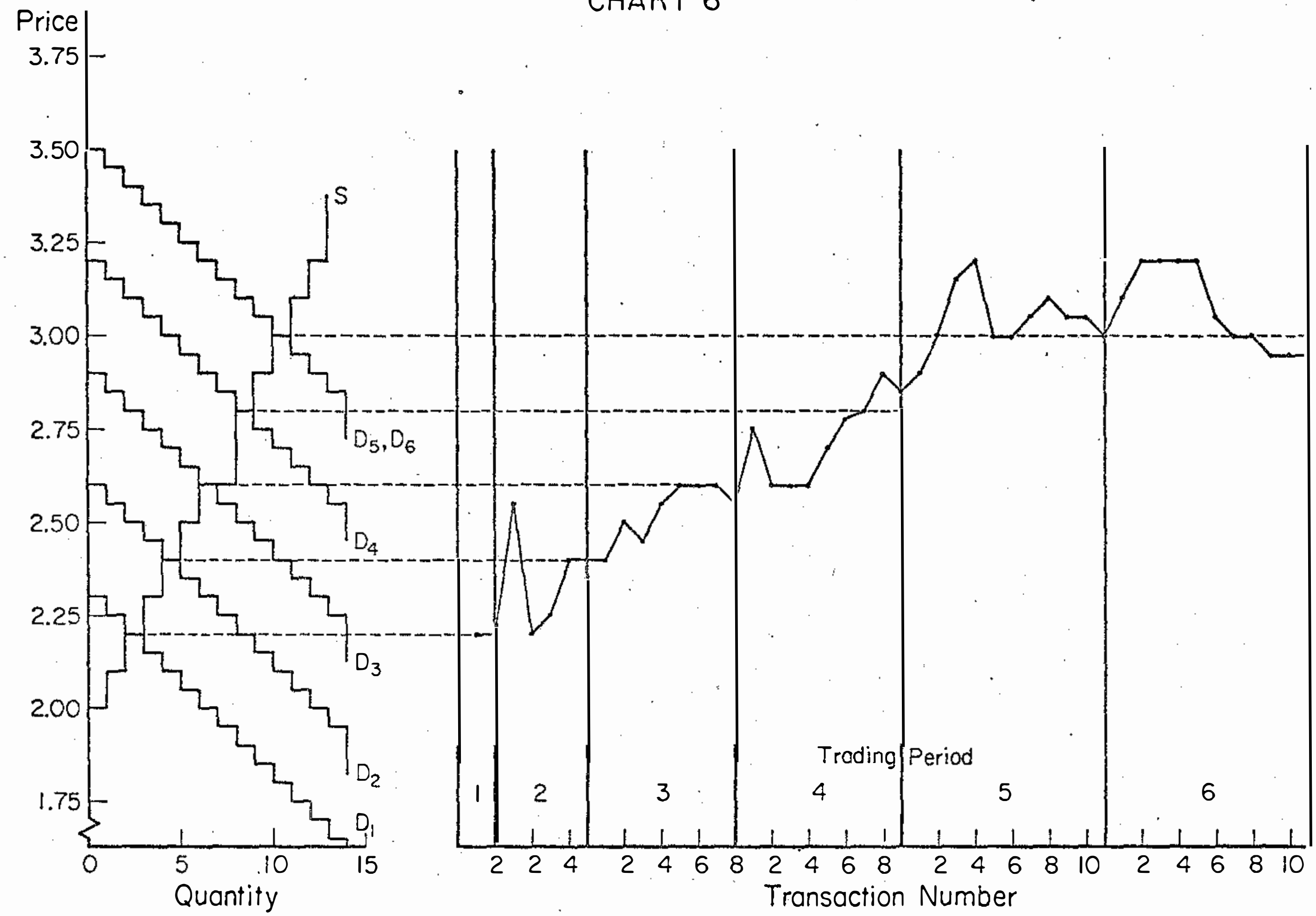
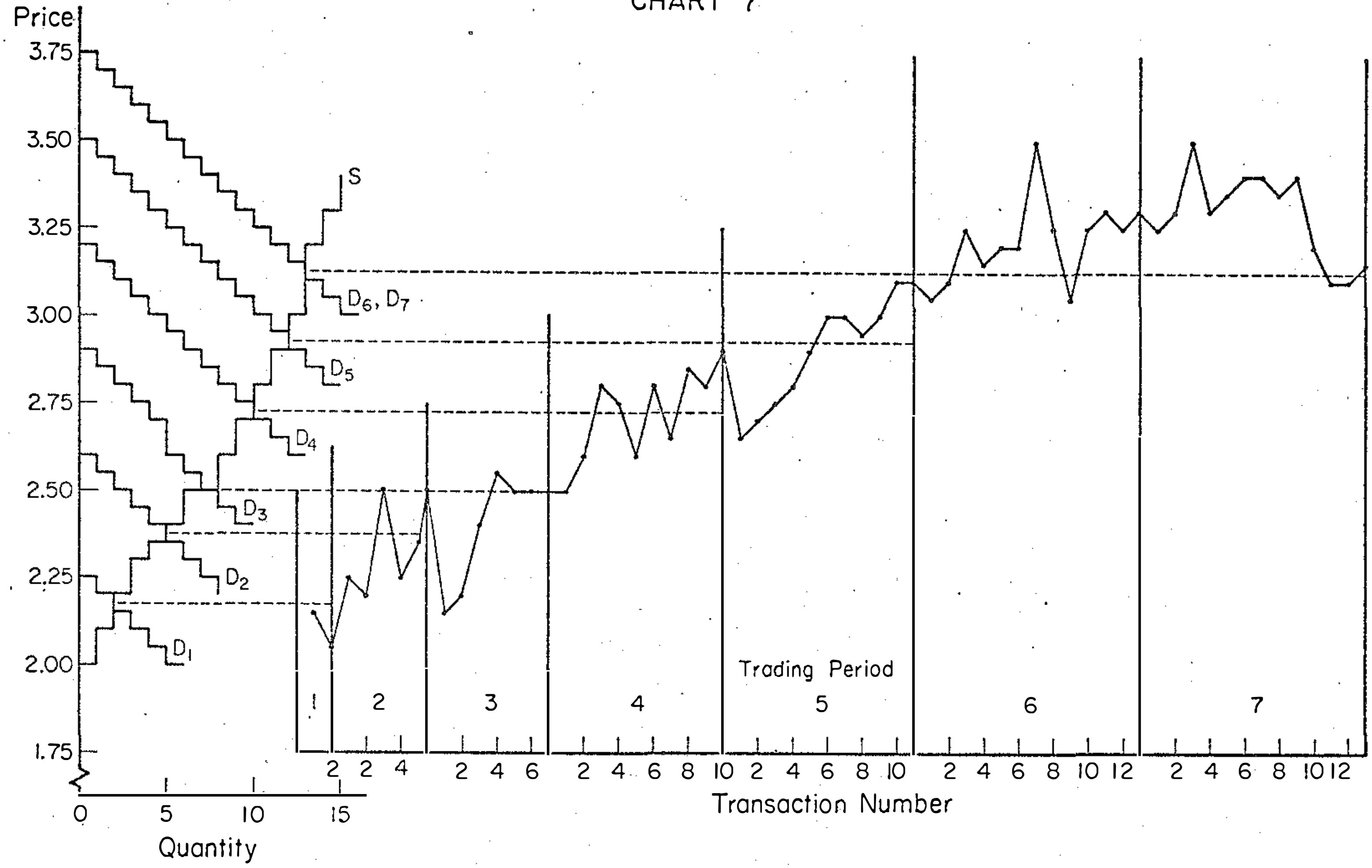

Price
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
S
D5, D6
D4
D3
D2
D1
0
5
10
15
Quantity
Trading Period
1
2
3
4
5
6
Transaction Number

CHART 7



Price
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
S
D6, D7
D5
D4
D3
D2
D1
0
5
10
15
Quantity
Trading Period
1
2
3
4
5
6
7
Transaction Number

FOOTNOTES

1. Charts 1 and 3 are reproduced from Smith (1962). Chart 2 reports a previously unpublished experiment.

2. In Chart 4, (a) and (b) are from experiments reported in Smith (1965); (c) and (d) are the results of previously unpublished experiments.

3. In Chart 5, (a) and (b) are from experiments reported in Smith (1965); (c) is based on a previously unpublished experiment.

REFERENCES

Arrow, K. "Price-Quantity Adjustments in Multiple Markets with Rising Demands." In Mathematical Methods in the Social Sciences, edited by K. Arrow, S. Karlin, and P. Suppes, Ch. 1, pp. 3-15. Stanford: Stanford University Press, 1960.

Arrow, K., and Capron, W. "Dynamic Shortages and Price Rises: the Engineer-Scientist Case." Quarterly Journal of Economics, vol. 75 (May 1959): 292-308.

Battalio, R.; Kagel, J.; Winkler, J.; Fisher, R.; Basmann, R.; and Krasner, L. "A Test of Consumer Demand Theory Using Observations of Individual Consumer Purchases." Western Economic Journal (December 1973): 411-428.

Carlson, J. "The Stability of an Experimental Market with a Supply-Response Lag." Southern Economic Journal, vol. 33 (January 1967): 305-321.

Coase, R. "The Problem of Social Cost." Journal of Law and Economics, vol. 3 (1960): 1-44.

Fouraker, L. and Siegel, S. Bargaining Behavior. New York: McGraw-Hill, 1963.

Hess, A. "Experimental Evidence on Price Formation in Competitive Markets." Journal of Political Economy, vol. 80 (March/April 1972): 375-385.

Knight, F. Risk, Uncertainty and Profit. London: London School Reprints of Scarce Works, No. 16, 1933.

Leibenstein, H. "Organizational or Frictional Equilibria, X-Efficiency, and the Rate of Innovation." Quarterly Journal of Economics, vol. 83 (November 1969): 600-623.

Plott, C. and Smith, V. "An Experimental Examination of Two Exchange Institutions." California Institute of Technology, 1975.

Shapley, Harlow. Of Stars and Men. Boston: Beacon Press, 1964

Sherman, Roger. "The Psychological Difference Between Ambiguity and Risk." Quarterly Journal of Economics vol. 88 (February 1974): 166-169.

Shubik, Martin. Strategy and Market Structure. New York: John Wiley and Sons, 1959.

__________. "A Trading Model to Avoid Tâtonnement Metaphysics." Cowles Foundation Discussion Paper No. 368, February 13, 1974.

Siegel, S. "Decision Making and Learning under Varying Conditions of Reinforcement." Annals of the New York Academy of Sciences vol. 89, 1961, pp. 766-783.

Siegel, S. and Fouraker, L. Bargaining and Group Decision Making. New York: McGraw-Hill 1960.

Smith, V. L. "An Experimental Study of Competitive Market Behavior." Journal of Political Economy vol. 70 (April 1962): 111-137.

____________. "Effect of Market Organization on Competitive Equilibrium." Quarterly Journal of Economics (May 1964): 181-201.

____________. "Experimental Auction Markets and the Walrasian Hypothesis." Journal of Political Economy vol. 73 (August 1965): 387-393.